TECHNICAL MEMORANDUM

Indirect Benefits (Increased Roof Life, and HVAC Savings) from a Solar Photovoltaic (PV) System at the San José Convention Center

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Introduction

The City of San Jose is considering the installation of a solar photovoltaic (PV) system on the roof of the San José Convention Center. The installation would be on a lower section of the roof covering approximately 21,000 ft^2. To assist city staff in making a decision on the PV installation, the Department of Energy Tiger Team has investigated potential indirect benefits of installing a solar PV system on the Convention Center roof. The indirect benefits include potential increase in roof life, as well as potential reduced heating and cooling load in the building due to roof shading from the PV system. The roof areas in consideration for the proposed PV system are shown as Area #1 and #2 in Figure 1 below:

Figure 1: Conceptual layout of solar PV system at the 4th Street City Parking Garage

For the purposes of this report, this analysis will cover Areas 1 and 2, consisting of about 21,000 ft^2. The roof area is shown in Figure 2 below:

Figure 2: Roof Area of interest for the San José Convention Center

The conceptual PV system would cover approximately 18,900 square feet (ft^2). The remaining portions of the roof (approximately 2,100 ft^2) would be used for walkways or spacing away from the parapet. The PV system would be installed on top of existing gray asphalt roof.

Purpose

The purpose of this memorandum is to estimate the indirect benefits of the PV system that may include lower Heating, Ventilation And Cooling (HVAC) loads due to the shading on the roof from the PV system. Another potential benefit is an extended roof life due to coverage from the PV system. If these benefits could be estimated and quantified, the net present value of installing a roof-mounted PV system would be higher than when just calculating the energy production of the PV system. The indirect benefits could theoretically sway the Return on Investment metrics to the point that an investment in a solar PV installation is enabled.

Potential HVAC Reduction Analysis

The roof areas under consideration were analyzed with a building energy modeling tool owned by the Department of Energy. The program, eQuest, models a building's HVAC load based on climate plus weather patterns, size of building, type of roof, color of roof, energy consumption, and a number of parameters of the building envelope. The Tiger Team also contacted SunPower, whose product PowerGuard™ is marketed as a total overall package that is able to reduce building cooling load, in addition to providing solar power to the building.

SunPower's in-house engineers used eQuest to model average commercial facilities across the United States. Their results show an improvement of ½ kWh/ft^2/yr savings for an average commercial facility in the U.S.

The Tiger Team took a closer look at the specifics of the Convention Center, and how the Convention Center's performance would change if a solar PV system were applied to the lower roof in Areas 1 and 2. A mechanical engineer with eQuest experience out of CH2M HILL's Dallas, TX office performed the analysis. After running initial models, the Tiger Team held a teleconference with SunPower to confirm the inputs and assumptions in the model.

<u>Assumptions and Inputs:</u>

- Original Roof: Light grey roof, characterized as Medium.
- Original Roof: R-19 insulation under the existing roof (based on As-Built Drawings for the Convention Center)
- Original Building: DX coils and no heating
- Solar Roof (Covered portion): Dark Color surface
- Solar Roof (Covered portion): R-10 Insulation (air gap not modeled, but would improve performance)
- Solar Roof (uncovered portion): Light roof (White membrane)
- Solar Roof (uncovered portion): No extra insulation
- *Note for inputs and assumptions:*

    The eQuest model does not have a feature that would allow for a solar system with an air gap between the PV surface and the insulation. Thus, the model considers the solar system as if the dark cell surface is bonded directly to the R-10 insulation. In real world situations, the temperature should be lower, as the air gap would slow the heat transfer from the PV surface to the insulation. The air gap would also allow air to flow in the interstitial space between the PV backing and the insulation, acting as a convective heat transfer agent to carry the heat from the modules away.

    Because the model does not have this feature, extensive modeling with a Computational Fluid Dynamics (CFD) software package would be required, and the results fed into a building modeling package. Without the CFD model results, it is reasonable to assume that the actual results of a PV system on a building would perform better (in a relative sense, when compared to a building with a normal roof) than the eQuest model suggests.

An eQuest modeling run was performed on the original building (before the PV system). The model was based on a building in San Jose California with an R-19 insulation, and a grey asphalt roof.

It is found that the original roof (modeled as a small building, 21,000 ft^2) would have an estimated annual consumption from HVAC loads (expressed in terms of kilowatt hours per year (kWh/yr)), as shown in Table 1 below:

Table 1: eQuest model results of the building before the PV system

	Roof type	Insulation	Roof Area	Estimated Building Load	
Original building	Medium	R-19	21,000	65,880	kWh/yr

Again, as the model is trying to model only this small portion of the roof, this is not the expected load of the entire convention center. The analysis is focused on a section of the lower roof, covering approximately 21,000 ft^2.

The estimation of the roof with the PV system covering 90% of the roof area is modeled as a dark surface with R-10 insulation on the back. The remaining 10% of the new roof would be modeled as a light reflective surface.

The results of the model are listed in Table 2 below:

Table 2: eQuest Results for a Power Guard™ PV system

	Roof type	Insulation	Roof Area	Estimated Building Load	
Roof covered with PV	Dark	R-19 + R10	18,900	60,960	kWh/yr
PV roof with white walkway	Light	R-19	2,100	6,320	kWh/yr
Combined PV+walkway roof	Dark+Light	R-19 +	21,000	67,280	kWh/yr

As shown in Table 2, the resulting 21,000 ft^2 has a higher modeled building load (67,280 kWh/yr) when compared with the original building model (65,880kWh/yr). The resulting increase in the building's HVAC load is about 2%. Again, it should be noted that the model does not factor the air gap between the module and the insulation. This air gap would provide insulation between the high temperature solar module and the insulation. It is reasonable to assume that this air gap would reduce the HVAC load by 2%, or greater; however, this was not modeled as the expense of modeling this system was not within the budgetary scope of this exercise.

As a note, it is expected that a mid-efficiency solar PV system (163kW$_{DC}$) would produce about 220,000 kWh/yr, so the PV production far outweighs the modeled building increase in heat load (1,400 kWh/yr).

Extended Roof Life

One other potential benefit of a solar PV system is an extension of the roof life. Representatives from Solar module producer SunPower believe that a PowerGuard™ PV system would increase the life of the roof below, as there would be less thermal cycling, less wear due to maintenance staff walking on the roof, and the PV system would protect the roof areas from UV. The rationale for these benefits is reasonable, as the PV system would shield the roof from UV, some degree of lower thermal cycling, and create minimal opportunities for foot traffic.

During site visits to cities such as Orlando, San Jose, Santa Rosa, Austin and others, it is found that the roof portions that are shaded by PV are about 20°F lower in the afternoons than the un-shaded areas. This confirms the claim that lower thermal cycling is possible.

As the cost of replacing a roof is known, it is possible to claim a potential savings from extending a roof life. For example, solar installers have claimed net present value savings of up to \$3.00/ ft^2 are possible (numbers based on extending a 10 year roof to 20 years).

While the concept of roof life extension may be reasonable, the roofing contractor will still determine the warranty period of the roof. A 10 year roof may experience a longer life than the original 10 year expectation, but a warranty extension based on a PV covering is highly unlikely. Without long term field data, the roofing and building industry will likely need a better understanding of the roof life extension benefits before committing to an extended warranty.

Summary

Potential roof benefits may include a reduced HVAC load, and extended roof life in some cases. A PV system is believed to extend the life of the roof membrane due to the lower degree of thermal expansion, reduced UV, and reduced mechanical wear (as people would not walk on the roof under the solar modules).

The analysis in this report (although unable to model the air-gap between the solar module, and the insulation) showed a slight (2%) increase in the building's HVAC load for a building 90% covered with a SunPower PowerGuard™ PV system, compared with the original building with existing R-19 insulation. The analysis was modeled in San Jose climate and weather data.

While indirect benefits to the building HVAC system and extended roof life are entirely possible, this report did not find a strong argument that these indirect benefits are quantifiable. Based on the findings, it is difficult to apply a monetary equivalent amount to the indirect benefits that a solar system provides.